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Status Report

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Response of Centrifugal Blowers to Simulated Tornado Transients

July—September 1981

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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Response of Centrifugal Blowers to Simulated Tornado Transients

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RESPONSE OF CENTRIFUGAL BLOWERS TO SIMULATED TORNADO TRANSIENTS

JULY--SEPTEMBER 1981

by

E. S. Idar, W. S. Gregory, R. A. Martin, and P. E. Littleton

ABSTRACT

During this quarter, quasi-steady and dynamic testing of the 24-in. centrifugal blower was completed using the blowdown facility located at New Mexico State University. The data were obtained using a new digital data-acquisition system. Software was developed at the Los Alamos National Laboratory to reduce the dynamic test data and create computer-generated movies showing the dynamic performance of the blower under simulated tornado transient pressure conditions relative to its quasi-steady-state performance.

Currently, quadrant-four (outrunning flow) data have been reduced for the most severe and a less severe tornado pressure transient. The results indicate that both the quasi-steady and dynamic blower performance are very similar. Some hysteresis in the dynamic performance occurs because of rotational inertia effects in the blower rotor and drive system. Currently quadrant-two (backflow) data are being transferred to the LTSS computer system at Los Alamos and will be reduced shortly.

I. INTRODUCTION

This report is a summary of our activities on our program for ventilation component testing for tornado transients for the period of July 1981 through September 31, 1981.

In this quarter, our work concentrated on completing quasi-steady and dynamic testing of the 24-in. centrifugal blower. Therefore, this report will focus on the blower testing aspects of this program.

II. EXPERIMENTAL PROGRAM

A. Blower Test Configuration

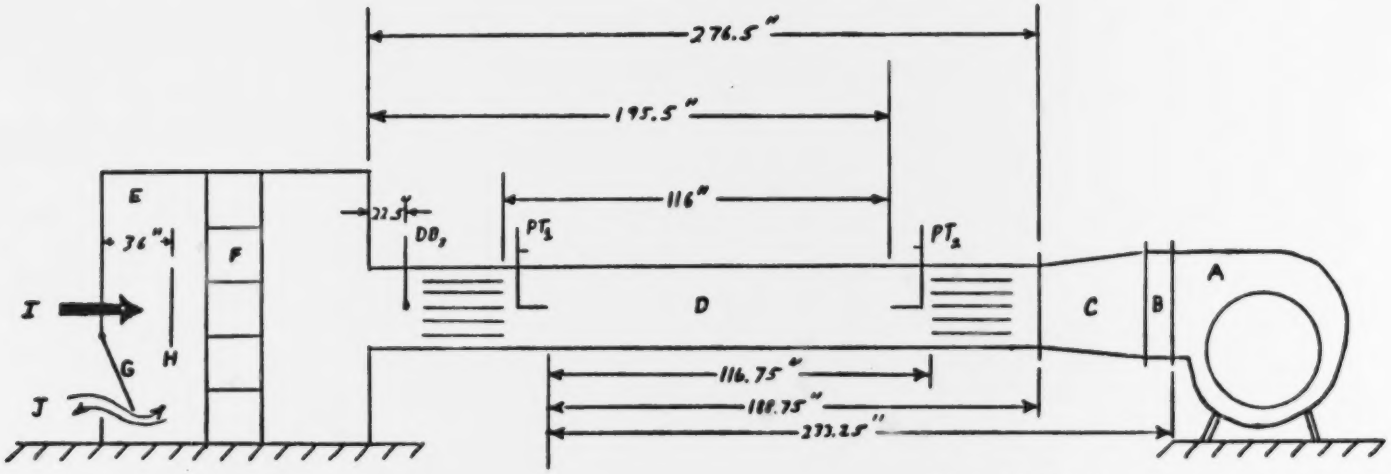
The general testing configuration used in this program is illustrated schematically in Fig. 1. The configuration used for obtaining quadrant-two quasi-steady and dynamic blower performance is shown. The blower is simply reversed for quadrant-one and quadrant-four testing. These configurations conform closely to those presented in AMCA standard 210-74 for steady-state blower testing.

1. Quasi-Steady-State Testing. Quasi-steady-state (QSS) data are obtained by initially running the blower at steady-state conditions and then increasing the pressure with the blowdown facility in a step fashion (Fig. 2). This pressure input forces the blower to operate in quadrant two or four depending on which side of the blower receives this input. In this fashion, we can generate a quasi-steady blower performance curve for nonaccident (quadrant one) as well as accident (quadrants two and four) flow regimes.

2. Dynamic Testing. The dynamic tests involve simulating an actual tornado pressure transient. Again, this is achieved using the blowdown facility located at New Mexico State University (NMSU). A representative simulated tornado pressure transient input for a dynamic test is shown in Fig. 3. The pressure profile consists of a constant rate of pressurization up to some pressure that remains constant for several seconds and then returns to ambient pressure at a constant depressurization rate equal to the pressurization rate.

For this series of tests, three pressurization rates and two peak pressure levels were used for a total of six combinations of pressurization rate and peak pressure. The pressurization rates were 2.0 psi/s, 1.2 psi/s, and 0.6 psi/s, which correspond to region I-, II-, and III-type tornados respectively. The peak pressures used were 0.5 psig and 1.0 psig. Although these pressures are lower than those associated with the characteristic region I-, II-, and III-type tornados, they were sufficient to produce the same flow rates through the system that were observed in the large-scale ventilation model testing that did simulate the appropriate peak pressures for these types of tornados. Because the blower test configuration does not represent a typical ventilation system,

A = 24-in. NYB 249 II blower
B = Vibration isolation coupling, 8 in.
C = Transition duct, 36.50 in.
D = 22.5-in. square duct
E = 1000 ft^3 volume, 10- x 10- x 10-ft
F = Filter bank (HEPA)



*Not to scale

G = Throttle door, 24 in. x 48 in.
H = Diffuser plate, 27 in. x 27 in.
I = Flow source from solenoid valves (blowdown)
J = Steady-state airflow

Fig. 1.
Schematic diagram of the blower testing facility.

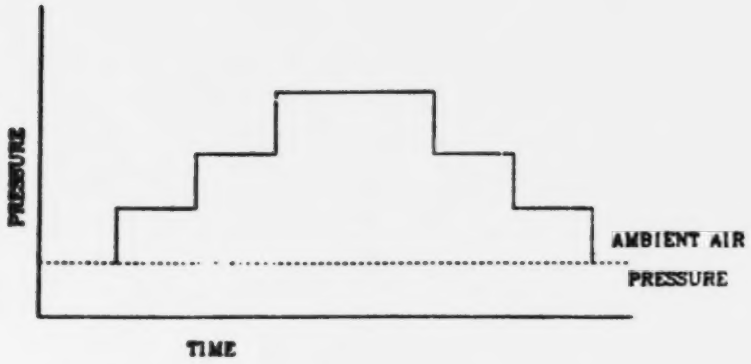


Fig. 2.
Pressure input profile for QSS blower test.

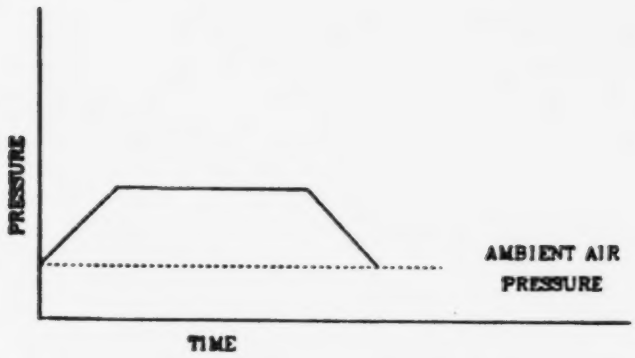


Fig. 3.
Pressure input profile for dynamic (tornado simulation) blower test.

equivalent flow rates are achieved with lower peak pressures because of the lower flow resistance of the blower test configuration.

III. EXPERIMENTAL RESULTS

A. Quasi-Steady-State Test Results

Figure 4 presents the current QSS data (triangular symbols) that have been reduced. Additional data points were obtained in quadrant two to flow rates of -11 000 cfm, but they have not been reduced. The solid line in the figure represents a least-squares cubic-spline fit of the data. Note that both quadrant-two and quadrant-four performance data are nonlinear but are approximated well with the curve-fit.

B. Dynamic Test Results

In performing the dynamics tests, we measured five time-varying parameters. These parameters include two temperatures, two pressures, and the blower speed. The data-acquisition system records these data sequentially, and therefore, these five parameters are slightly out of phase (in time) with each other. To correct for this effect, the raw data are curve-fitted very accurately with a least-squares cubic-spline algorithm. These parameters then are regenerated at the same time increment using the curve-fit. An example of the raw data with the curve-fits is shown in Figs. 5--7. The symbols represent experimental data points, and the solid lines represent the curve-fits.

Dynamic data have been reduced for two cases where the blower is pulsed through the inlet, which forces it to operate in quadrant four. The first case is for a pressure transient with a pressurization rate of 0.6 psi/s to a peak pressure of 1.0 psig. The second case has a pressurization rate of 2.0 psi/s to a peak pressure of 1.0 psig.

Figure 8 presents the dynamic performance of the 24-in. centrifugal blower for the first case. In this figure the curve-fitted QSS data are shown by a solid line, and the dynamic performance is shown by a dashed line and a symbol. The symbol in the figure represents the current operating point of the blower at the time indicated. The dash indicates the dynamic performance behavior at all previous times. The tornado transient pressure simulation is also shown. At $t = 1.0$ s, conditions are at steady state, and the blower is functioning at a nominal steady-state operating point in quadrant one. At $t = 2.0$ s, the pressure transient has begun, and the blower operating point begins to change with time and moves off the QSS curve slightly. The volume flow rates for a given

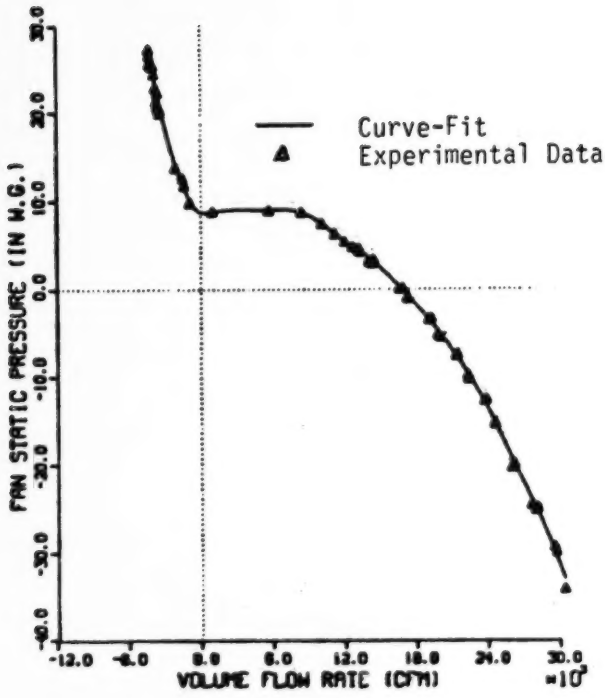


Fig. 4.
QSS performance results for the 24-in. centrifugal blower.

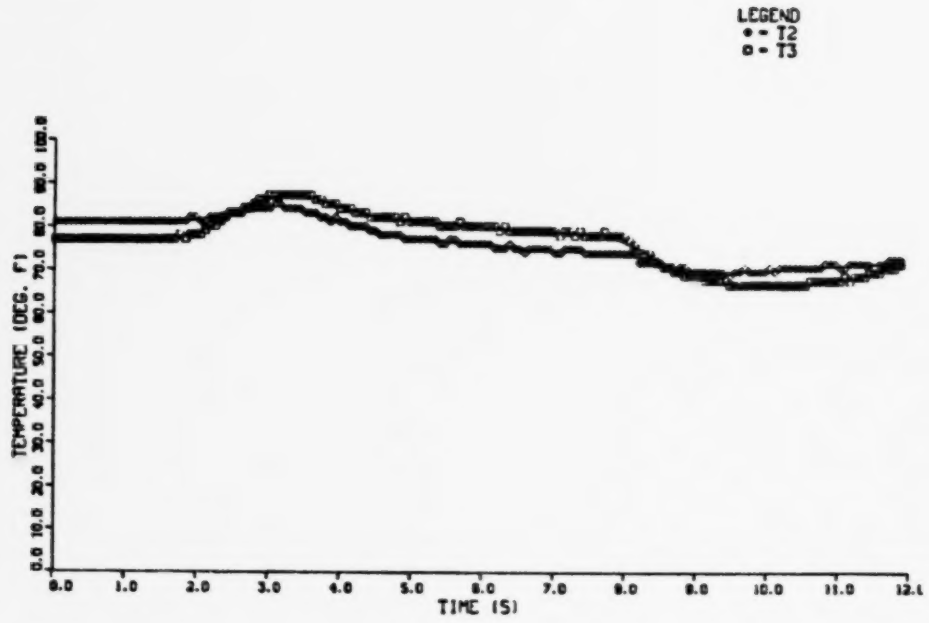


Fig. 5.
Temperature data and curve-fits for a dynamic test of the 24-in. centrifugal blower.

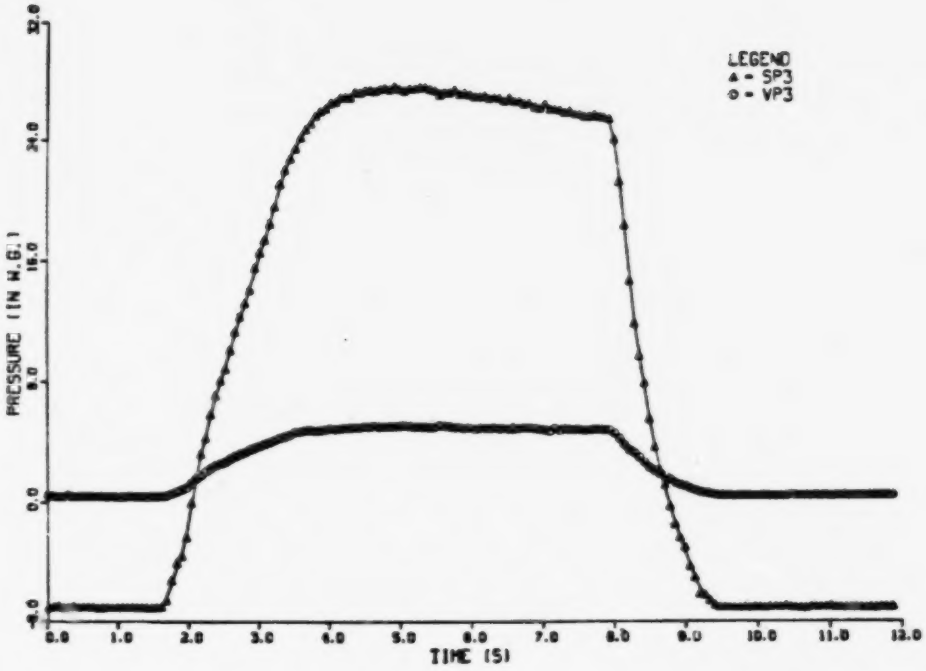


Fig. 6.
Pressure data and curve-fits for a dynamic test of the 24-in. centrifugal blower.

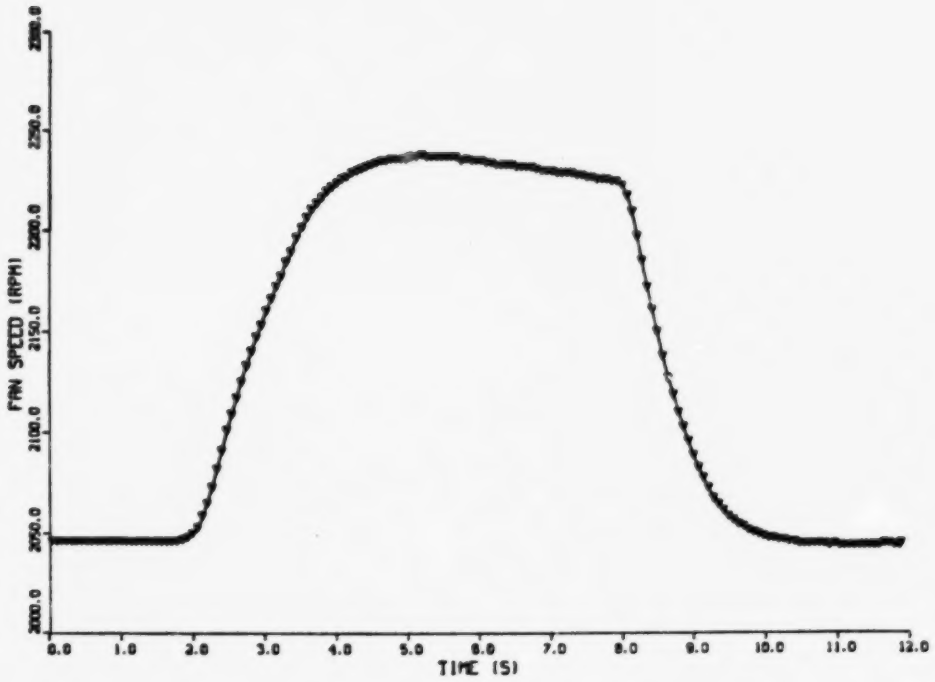


Fig. 7.
Fan speed data for a dynamic test
of the 24-in. centrifugal blower.

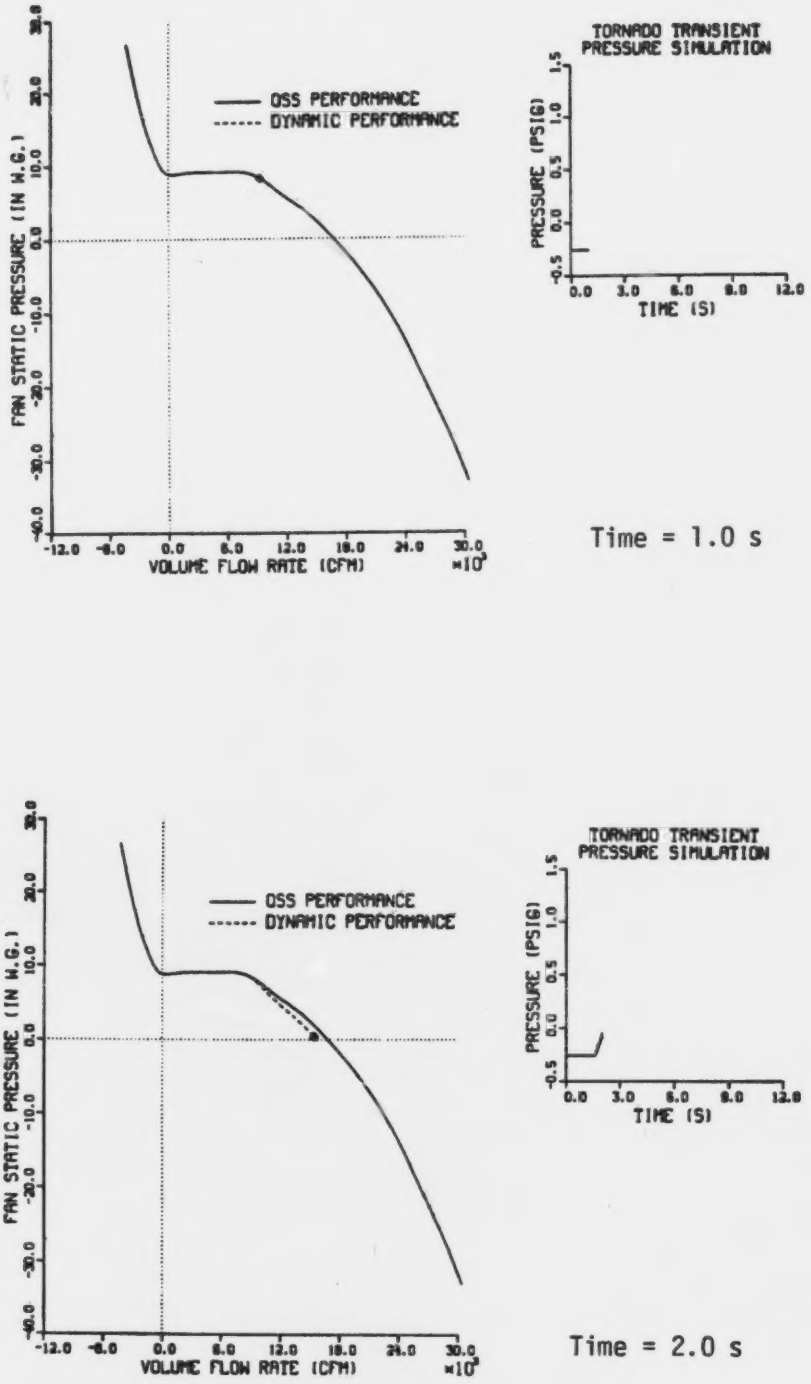
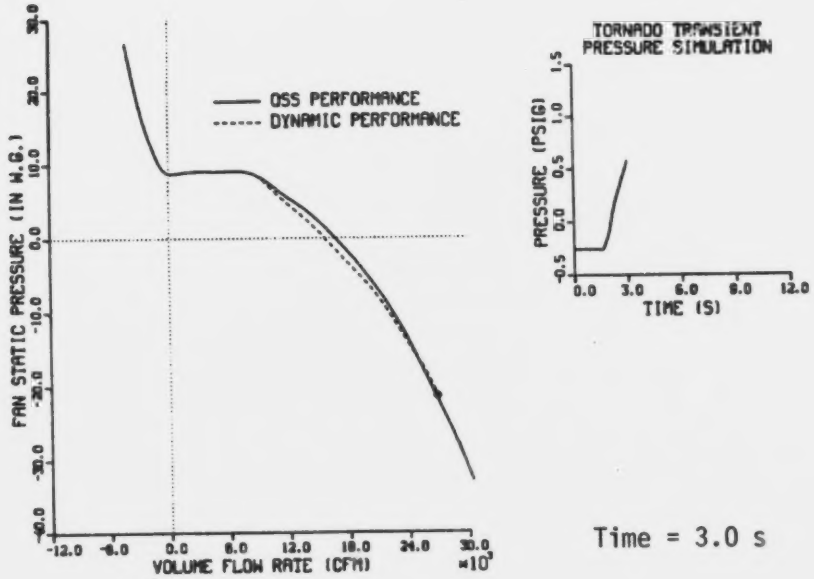


Fig. 8.
Dynamic response of the 24-in. centrifugal blower to a tornado transient pressure simulation with a pressurization rate of 0.6 psi/s and a peak pressure of 1.0 psig.



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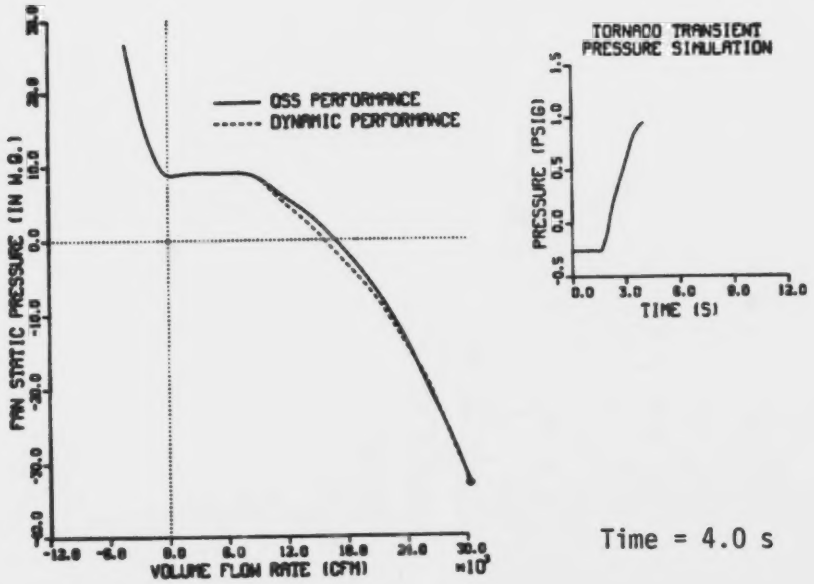

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Fig. 8.
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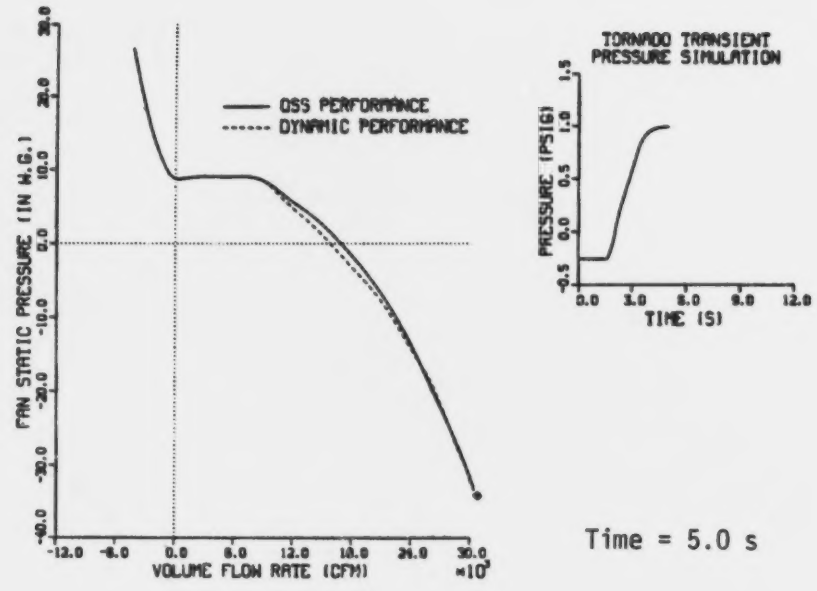

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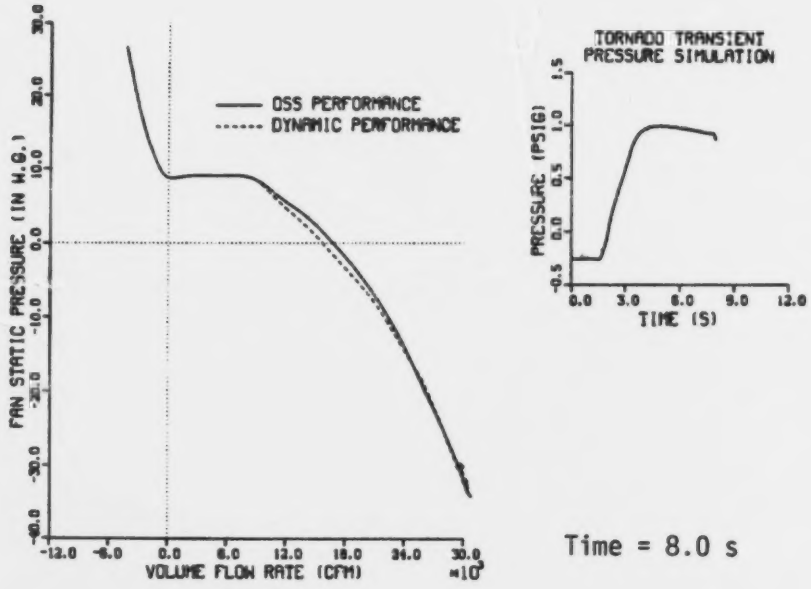

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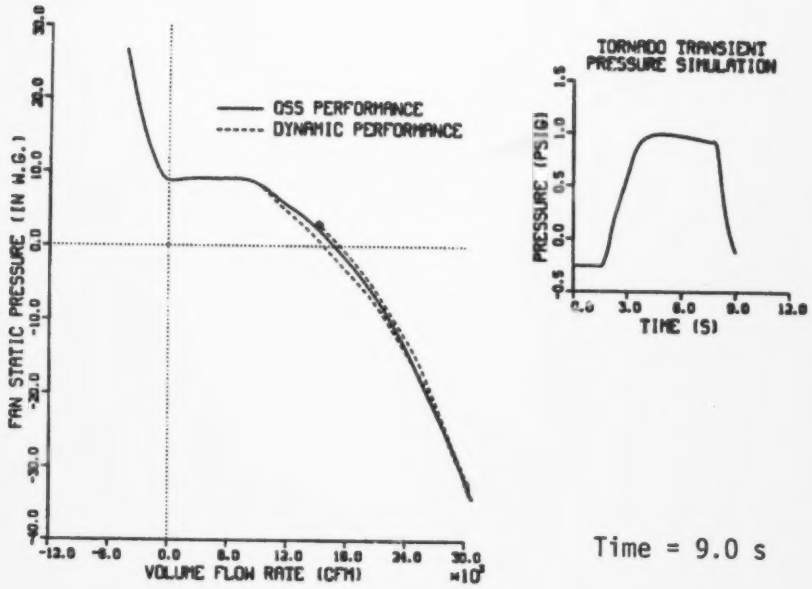

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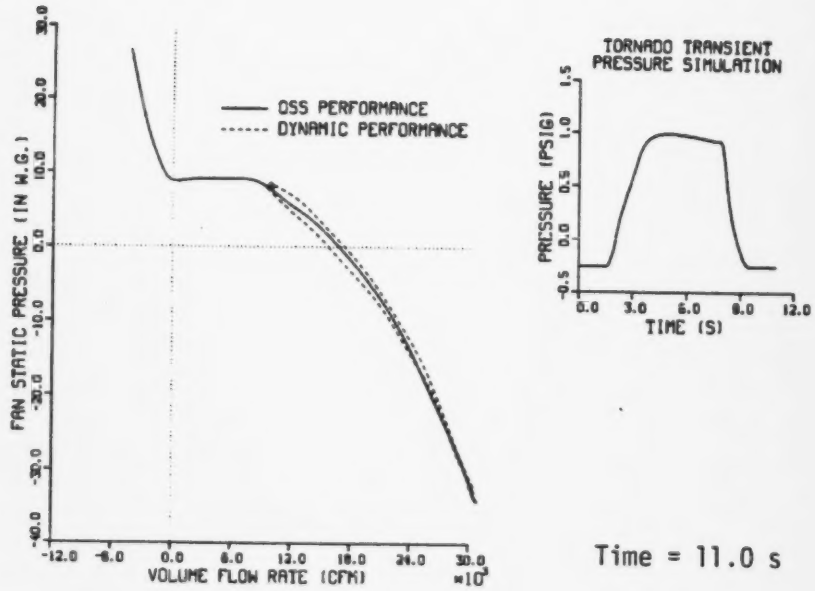

Time = 11.0 s

Fig. 8.
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fan static pressure are lower for the dynamic response at this time. This is a result of rotational inertia effects in the blower rotor and drive system that prevent the blower speed from responding instantaneously to the pressure transient. At 3 s, the blower has begun to respond (that is, accelerate), and the operating point moves back to the QSS curve. At 4 s, the pressure begins to reach its peak, and the blower achieves a QSS operating point in quadrant four. From t = 8 s to t = 11 s, the pressure drops back to its steady-state value, and the blower responds accordingly and returns to its initial steady-state operating point.

Figure 9 shows the dynamic response for the second and most severe case tested. The pressurization rate in this instance is 2.0 psi/s to a peak pressure of 1.0 psig.

Again, conditions are steady state at t = 1.0 s. At 2 s, the pressure has risen rapidly, and the blower responds. At 3 s, the pressure reaches a peak, and the blower achieves a QSS operating point. The pressure drops back to its steady-state value between 5 s and 6 s, and again the blower operating point returns to its initial value. More hysteresis is apparent for this transient in the dynamic response than in the first case. This is because it takes longer for the blower speed to respond to the higher pressurization rate.

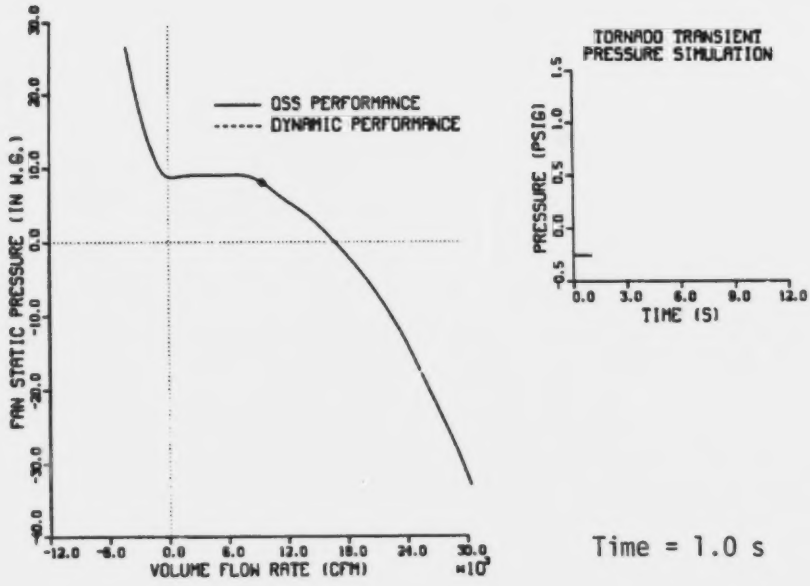
In either case, the dynamic response is approximated very well by the QSS performance curve for quadrant four.

Data for quadrant-two performance currently are being reduced and will be presented in the next quarterly progress letter.

Computer-generated movies were created for the two cases presented above, and they show the dynamic response on a continuous time-varying basis.

IV. SUMMARY

Based on the reduced test data presented above, we believe we can approximate dynamic blower response in quadrant one and quadrant four to simulated tornado pressure transients very well using QSS performance curves in these quadrants. The question as to whether this is also true for quadrant two will be answered when these data are reduced.



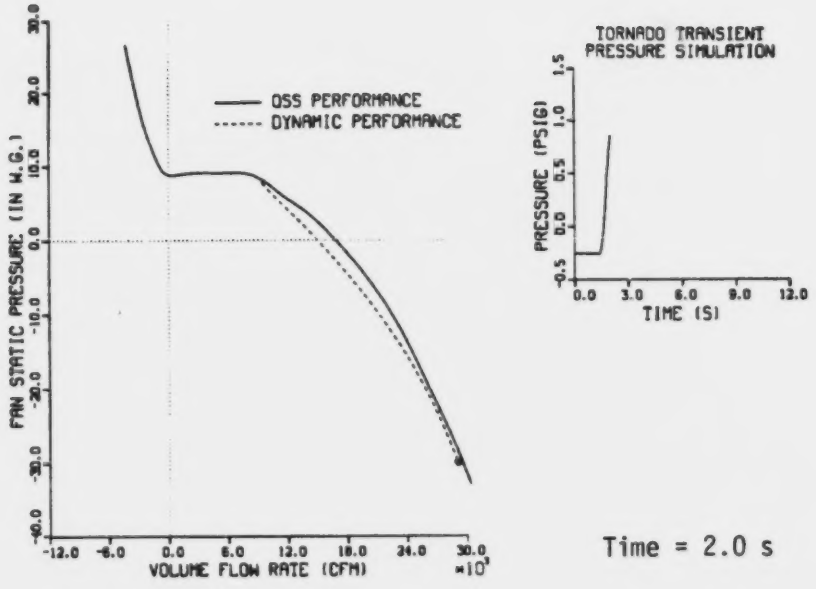
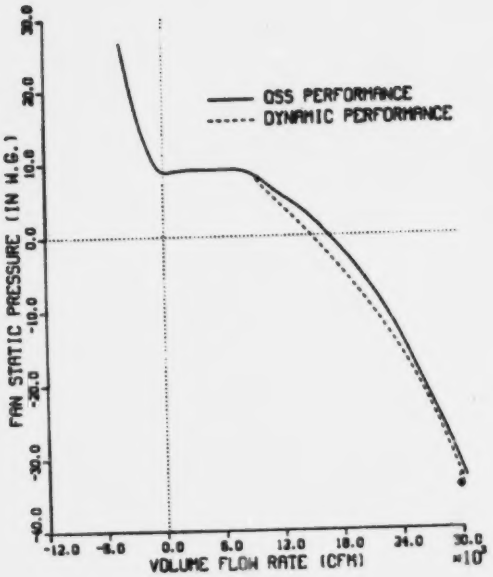
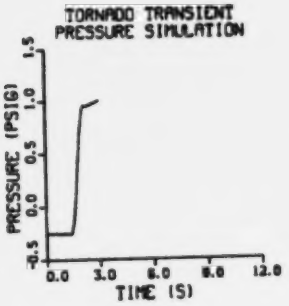


Fig. 9.
Dynamic response of the 24-in. centrifugal blower to a tornado transient pressure simulation with a pressurization rate of 2.0 psi/s and a peak pressure of 1.0 psig.





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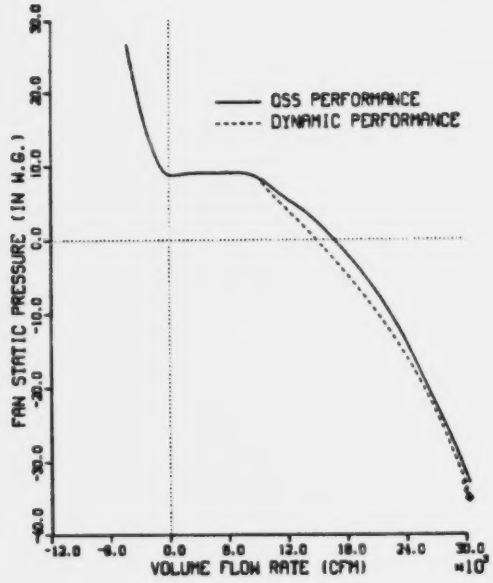

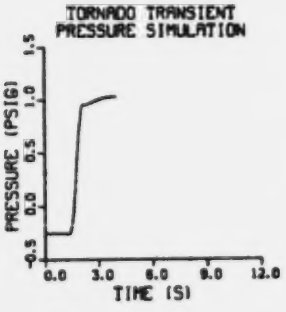

Time = 4.0 s

Fig. 9.
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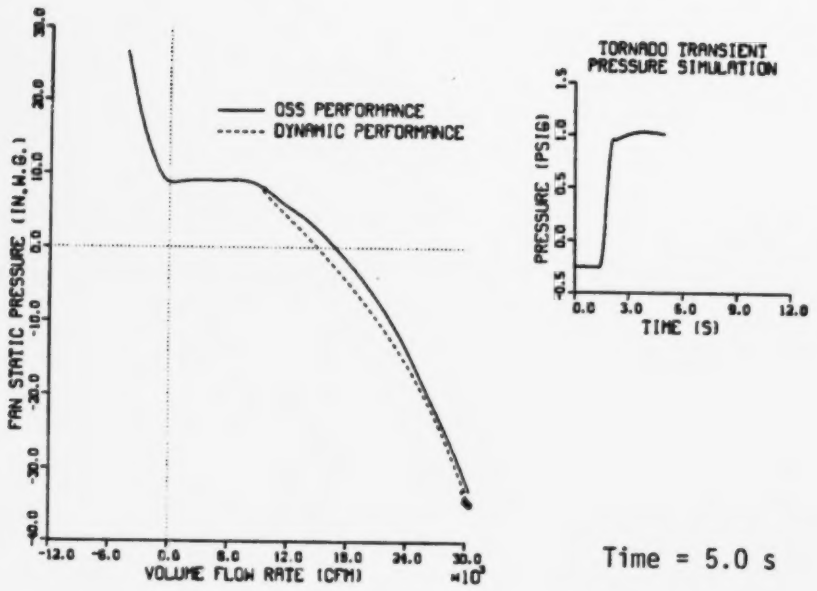

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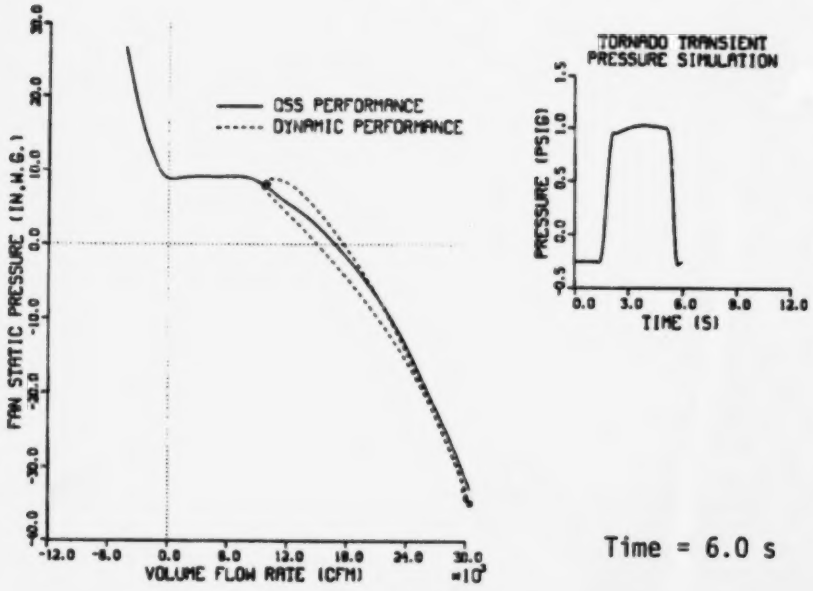

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Fig. 9.
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